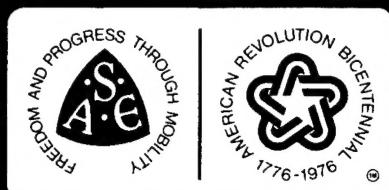


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EPDM for Exterior Trim Applications

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SOCIETY OF AUTOMOTIVE ENGINEERS

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EPDM for Exterior Trim Applications

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THE USE OF PAINTED, FLEXIBLE, EXTERIOR AUTOMOTIVE PARTS to help meet governmental requirements and reduce vehicle weight has grown substantially in recent years. This trend is expected to continue, especially for full fascia, as polymer producers, custom molders and car manufacturers gain experience with various candidate materials for this market.

Ethylene propylene rubber, commonly referred to as EPDM, has been used in substantial quantities for sight shields, bumperettes, rub strips and, to a limited extent, for full fascia parts. From all indications, EPDM is now on the threshold of a major breakthrough for full fascia applications.

EPDM is firmly established as a base material for flexible, painted, exterior parts for vehicle applications. Since 1973, when EPDM was successfully launched for sight shields on Ford and Chrysler cars, and as a bumper on GM's Camaro, some 40 million production parts have been turned out including bumper filler panels, bumperettes, rub strips and fascia. To date, over 100 million pounds of EPDM have been consumed for these applications.

SUPPLY BASE

Parts are produced by five suppliers who have invested \$30 million to build eight plants, specifically designed to manufacture painted exterior automotive parts on a mass production basis.

Now, in place are 40 injection molding machines capable of handling large fascia-type parts of EPDM. These machines have clamp pressures ranging from 1,000 to 3,000 tons, and are capable of producing any of the fascia designs

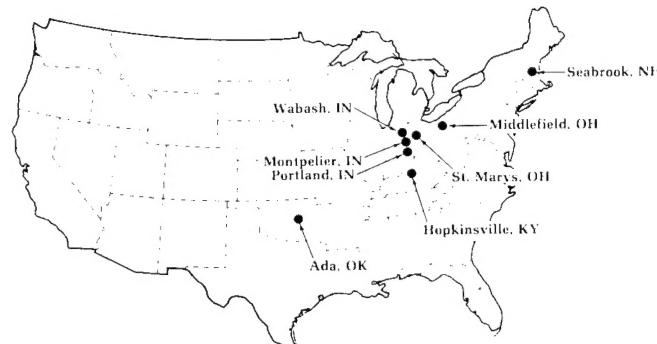


Figure 1 — Plant Locations EPDM Molders

currently specified or contemplated. Assuming that only single cavity tools are used, machines already in place could turn out over 3 million fascia parts annually — and a multiple of this figure if multi-cavity molds are employed.

This is an impressive supply base by any standard. If the adoption of soft fascia to reduce weight and to meet damage resistance requirements expands, as many in the industry foresee, a broad supply base must take on added significance in current and future planning.

Progress in EPDM technology and capability has been attained only through the dedication and cooperation of EPDM producers, machine manufacturers, parts producers and the automotive fraternity. Investment in research and development, and in plant and equipment has been huge. While no precise figures are available, total investment to date has to be measured in hundreds of millions of dollars.

ABSTRACT

The purpose of this paper is to review the current status of EPDM from the standpoint of applicable properties, availability, custom molder capabilities and commercial implications. Current EPDM applications are described and, where appropriate, comparisons are made with reaction

injection molded urethane (RIM) which, to date, has had the broadest usage in flexible fascia. In addition, anticipated developments in EPDM technology are described to give the automotive engineer and stylist an insight into possible EPDM capabilities in the future.

PROPERTIES OF EPDM

Obviously, EPDM possesses certain properties and advantages to merit this confidence. It was first introduced 13 years ago. From its inception, EPDM was hailed as a breakthrough in synthetic rubber chemistry because of its low cost; excellent resistance to deterioration from ozone, oxygen, weathering, heat and chemicals; high tear and tensile strength; excellent dynamic and low temperature properties; and good processability. Because of this attractive combination of properties, the use of EPDM, in both automotive and non-automotive applications, has steadily increased.

A versatile material, EPDM is a product of a hundred faces and is in widespread use today. For example, there are approximately 25 parts, such as vents and cellular seals, jackets, wire, hose, tubes, diaphragms, and so forth, fabricated from EPDM on every American automobile. The versatility of EPDM is not limited to compounding variations, but carries over to the method of production as well. Parts have been and continue to be made by all the standard rubber fabrication techniques such as extrusion, compression, transfer and injection molding.

Table I
Thermoset EPDM — Typical Properties

	Type I Cosmic Low-Abuse	Type II Functional Cosmic High-Abuse
Basic Properties		
Specific Gravity	~1.1	~1.25
Polymer Form	strip/slab	free flowing pellets
Processing Properties		
Mooney Viscosity	30-40	20-30
Cure Time (@ 375°F.)	1.0-2.0 min.	1.0-2.0 min.
Mechanical Properties		
Hardness	70-90A	40-50D
Tensile Strength, psi	2,000	2,000
Elongation, %	350	250
Flexural Modulus, psi @ R.T.	3,000	20,000
Compression Set, %	<20	<30
Thermal Properties		
Brittle Point, °F.	-40	-40
Max. Serv. Temp., °F.	300	300
Miscellaneous Properties		
Weathering	Excellent	Excellent
Ozone	Excellent	Excellent

Table II
Properties Unique to EPDM for Fascia

Temperature insensitivity
Impact resistance
Distortion resistance
Recovery from deformation
Dimensional stability

COMPOUNDING

The term EPDM does not refer to a single product. Rather, it refers to a class of materials. Du Pont, for example, produces 13 different types of EPDM, under the trademark "Nordel", all designed for different properties or end uses. Of itself, the raw polymer is not useful in many applications. Various ingredients, such as carbon black or clay fillers, processing oils and cross-linking agents, must be incorporated in the base EPDM polymer to yield a rubber compound which can be molded or extruded and then vulcanized to produce a finished product.

Table III
Compounding Ingredients Thermoset EPDM

1. EPDM polymer
2. Fillers — Reinforcing agents (carbon black, clay)
3. Extenders, Flexibilizers (oils)
4. Chain extenders and cross-linkers (e.g. sulfur)
5. Miscellaneous chemicals for varying state of reaction and improved resistance to oxidation, U.V., etc.

Choice of compounding ingredients and the amounts used are extremely important. They play a major role in determining processability, performance characteristics, and cost of the finished part. The number of possible combinations or recipes is almost endless and hundreds, perhaps thousands, of different EPDM rubber compounds are in commercial use today, ranging in hardness from 30A to 50D durometer. However, for exterior automotive trim, Du Pont produces pre-compounded EPDM, either in strip or pellet form, ready for molding.

While EPDM is available as either a thermosetting or thermoplastic material, fascia applications to date have used only thermoset EPDM. As a thermoset, it is both heat and shear sensitive. In contrast to a thermoplastic, it undergoes an irreversible chemical reaction during vulcanization. Although this thermosetting behavior produces some non-recyclable scrap, it does provide EPDM parts with several unique properties, including minimal high and low temperature sensitivity, along with excellent impact and distortion resistance. These properties are essential in many end uses and are especially important in flexible exterior vehicle applications.

Many of the properties which are unique to thermoset EPDM make it a viable candidate for flexible, exterior vehicle applications. Specifically, these properties are temperature insensitivity, impact resistance, resistance to distortion, recovery from deformation, and dimensional stability.

Temperature Insensitivity — This refers to EPDM's ability to maintain properties over a broad temperature range. At temperatures as low as minus 20°F., parts will not seriously stiffen or embrittle and, under impact, will not result in either transmittal of too much force to produce a dent or distortion in adjacent sheet metal, or in the catastrophic shattering of the part itself.

At elevated temperatures, EPDM parts exhibit minimal sag or droop. This helps insure the maintenance of character of

joint lines on the vehicle on a hot summer day. While assembly is not as routine as handling sight shields, its temperature insensitivity does offer some advantages over competitive materials.

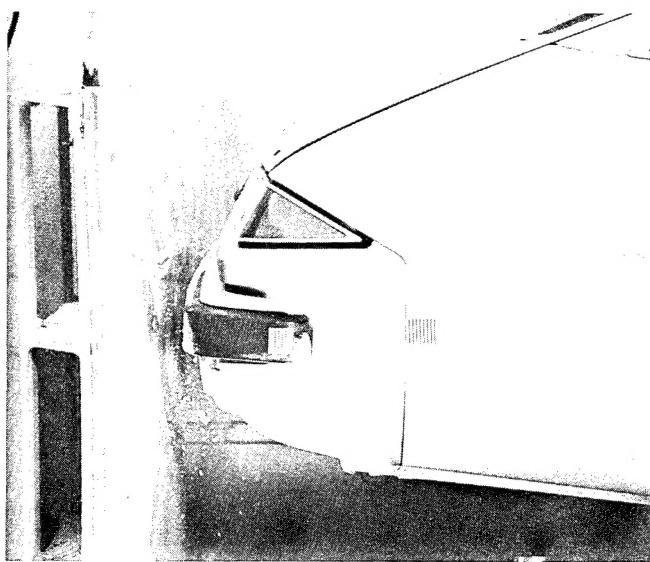


Figure 2 — EPDM Monza fascia survives low temperature impact test.

Distortion Resistance — The resistance of EPDM to distortion, which is a function of its resilience, is not unexpected since EPDM is a true rubber. This property is a very valuable asset for any exterior automotive part which will be subject to impact.

EPDM's ability to recover from deformation and its dimensional stability are somewhat related properties and are characteristic of all cross-linked thermoset rubbers. Recovery from deformation arises from the elastic memory of parts molded of EPDM — even after such parts are distorted.

Dimensional Stability — Because of its dimensional stability, parts of EPDM exhibit very low thermal expansion and contraction and, consequently, assembly and appearance problems are minimal. The newer fiber-reinforced EPDM fascia candidates are exemplary in this regard and will be emphasized in the following discussion on past and current applications of EPDM for exterior vehicle applications.

EPDM APPLICATIONS

3,000 Flex Modulus EPDM — The first EPDM offered to the industry was an 80A durometer, 3,000 flex modulus material. This type was designed to answer two specific needs: The first for a relatively soft flexible material which could be painted and used to fill the void between bumper face bar and the sheet metal, variously referred to as a sight shield, filler panel, stone deflector or close-out. The second need this EPDM was designed for was a thick-section, painted bumper. As stated previously, this EPDM was successfully applied in 1973 for sight shields on Ford and Chrysler cars and the loop bumper on the Camaro.

7,000 Flex Modulus EPDM — Another need EPDM satisfied was for a material to be used in bumperette applications. Here, a product having relatively high stiffness is required.

Consequently, EPDM candidates were formulated to provide a stiffness of up to 7,000 psi flex modulus. An example of this type of EPDM, successfully applied, is the bumperette application in the 1976 Monza 2 plus 2.



Figure 3 — Dotted line outlines lower rear fascia of Monza.

Tooling Adaptability — The Monza bumperette illustrates a significant difference in tooling adaptability between the nickel shell tools used for RIM parts and the steel tools used for EPDM. The 1975 Monza fascia was released in RIM. Between the 1975 and 1976 model years, the Federal Government imposed new bumper impact requirements, necessitating the addition of two bumperettes at the outboard corners of the lower fascia.

Had the 1975 Monza fascia been released in EPDM, the steel tools could have been reworked to incorporate the outboard bumperettes in the same mold. In contrast, the nickel shell tools used for the RIM fascia were too thin to be reworked. Faced with the option of completely retooling the fascia or adding separate parts, the lesser evil, even though it made assembly more complex, was to release two small EPDM bumperettes for the 1976 Monza rear bumper. From this experience, it is logical to conclude that steel tooling, used for EPDM, is much more adaptable to part design changes that involve appearance, functionality, or assembly complexity, than the shell tooling used for RIM. In addition to the Monza, the Oldsmobile Starfire and the Buick Skylark employ outboard bumperettes of EPDM.

Unlike the sight shield and bumperette applications which have remained relatively stable, elastomeric bumper design has changed significantly since the early seventies. Thick section parts, such as the Pontiac GTO nose bumper and the Camaro loop bumper, were obsoleted by the new concept of a thin flexible fascia. The reported advantages for this concept were: less hostile in impacts with other vehicles, less damage in low-speed collisions, lighter weight, and for comparable performance, probably less costly than hard-faced systems.

20,000 Flex Modulus EPDM — The fascia concept was first demonstrated on the well-known experimental

Chevrolet taxicab fleet and was first applied commercially on the Corvette. The advent of fascia necessitated the development of new EPDM materials that were significantly stiffer than those in existence. This led to the development

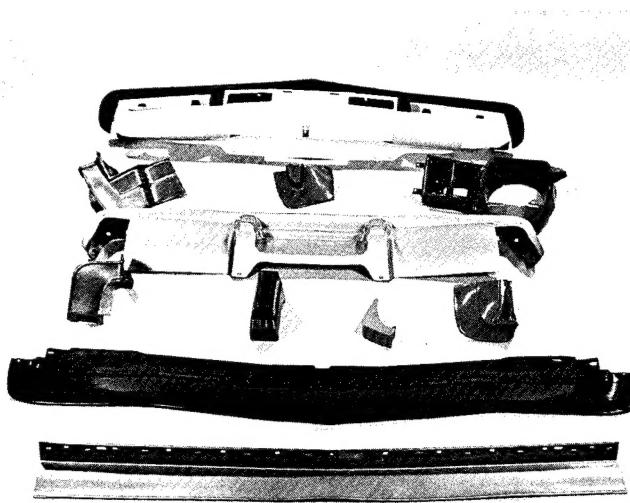


Figure 4 — Various exterior trim parts of EPDM use different stiffness grades.

of EPDM's having flex moduli up to a 20,000 psi range. Increased stiffness has been achieved by making use of the previously discussed compounding versatility of EPDM. In this instance, the addition of ingredients such as resins and fibers achieved the desired stiffness without sacrifice of important rubber properties.

The success of fiber addition to increase stiffness is evidenced by the release of glass-reinforced EPDM for the 1977 Oldsmobile Starfire. In addition, a fiber-reinforced EPDM in the same stiffness range, is in production for the 1977 Ford Pinto. A discussion of both of these applications follows.

The prototype for the 1977 Starfire was actually a 1,000 part deviation from RIM on the lower rear fascia of the 1975 Monza. The purpose of the program was to demonstrate the process, functionality on the car, and verify compatibility with fascia paint and assembly facilities.

As far as the process goes, it was demonstrated that the six pound lower rear Monza part could be injection molded in fast cycles of approximately 2 minutes, 15 seconds. A major advantage of EPDM in attaining this fast cycle time is that the EPDM part drops freely from the mold without the use of mold release agents. Had release agents been necessary, machine productivity would have been lower because of downtime required to clean the mold. With regard to functionality on the car, the glass-reinforced EPDM part withstood more impacts on the car and proved to be more resistant to splitting than its RIM counterpart, particularly at lower temperatures.

Handling Characteristics Vs. RIM. — In the assembly plant, a number of EPDM's handling characteristics were appraised including: shipping requirements, paint rack requirements, paint hiding capability, electrostatic paint application, and fascia assembly. These characteristics were compared with RIM to evaluate the basic differences in

the two systems. The mechanism by which a part retains its shape is different for EPDM than for RIM. EPDM relies on a combination of chemical cross-linking and crystallinity to maintain its shape. This means that even if the part is



Figure 5 — Oldsmobile Starfire showing front fascia.

intentionally distorted, it will return to its "as-molded" shape if the part is unrestrained and heated to about 250°F. The glass fiber content of this particular EPDM imparts a degree of stiffness, dimensional stability and heat resistance. It was anticipated that these properties would contribute to ease of handling, resistance to distortion and improved high temperature performance. Because EPDM materials contain a high proportion of carbon black, it also promises inherent conductivity for electrostatic paint application.

Part shipment was evaluated by eliminating the full shipping supports used with RIM, in order to study the tendency of the part to distort, then recover from deformation. This proved successful.

In this trial, it was also concluded that simple, low cost "minimal support" paint racks were feasible with EPDM in place of the line-for-line type of racks then used with RIM.

Painting Capability — There is a significant difference in paint hiding capability between EPDM and RIM. Because EPDM contains a substantial amount of carbon black, it is electrically conductive. At the custom molder's plant, EPDM is painted with a light gray primer, whereas RIM is painted with a black electrically conductive primer. When the color coat is applied, it is easier to achieve good paint hiding on the gray primer than on the black, particularly if film build up is on the low side. Because it is slightly stiffer than RIM at room temperatures, EPDM fascia proved to be somewhat easier to handle during assembly.

Oldsmobile Starfire — Shortly after the 1,000 car trial was successfully completed in 1975, Oldsmobile adopted EPDM for the lower front Starfire fascia. The part was retooled and resourced from RIM to EPDM as a cost reduction measure. It is significant that projected savings were sufficient to justify the expense of retooling. For start of production, the 1977 upper fascia of the Starfire is also made of EPDM.

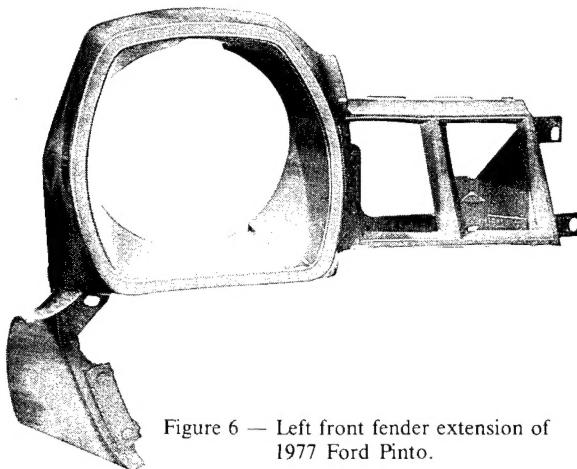


Figure 6 — Left front fender extension of 1977 Ford Pinto.

Ford Pinto — Another example of the use of 20,000 flex modulus material is the front fascia on the 1977 Ford Pinto.

The forerunner of this application was the successful experimental molding of a large 22 pound EPDM front fascia for the Ford Torino. The part molded beautifully and helped convince Ford Engineering to adopt EPDM for the high volume production run scheduled for the 1977 Pinto.

The fascia consists of right and left front fender extensions which surround the recessed head lamps and parking lamps. To facilitate mounting to the fender, the extension is backed by a metal stamping. Completing the front-end design is a one-piece stone deflector, fabricated from a non-reinforced EPDM compound. The fascia parts are molded in thin sections — .090/.100 in. and thus take advantage of the stiffness imparted by the 20,000 psi modulus of the EPDM compound. This facilitates assembly and the dimensional stability of the EPDM contributes to the good fit required by Ford. The 1977 Pinto marks the first use by Ford of a high visibility flexible exterior part.

In addition to these fascia applications, the 20,000 flex modulus EPDM is used for painted rub strips on the current Laguna and the Chevrolet and Oldsmobile station wagons. The stiffness of the material eliminates the need for metal reinforcement. Mounting studs are molded directly into the rub strips, contributing to lower overall costs.



Figure 7 — Ford Pinto showing front fascia assembly.

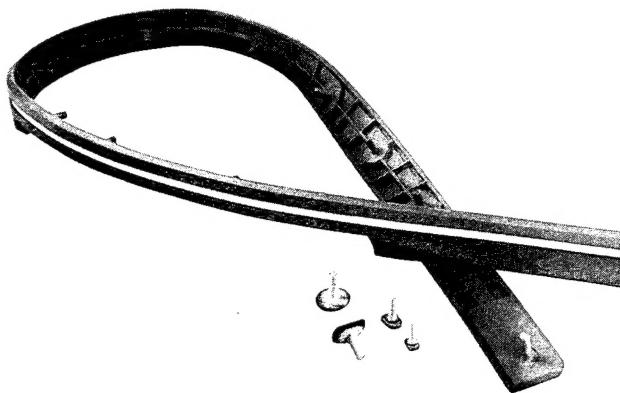


Figure 8 — Mounting studs are molded into EPDM rub strip.

100,000 Flex Modulus EPDM — A recent breakthrough in EPDM material development is the commercialization of a polyester-fabric reinforced EPDM which can provide stiffness up to 100,000 flex modulus. It has been released by GM as a low weight, low cost energy manager on its new RTS-2 coach. It is combined with a glass filled, painted EPDM fascia, and is the first application of a highly stylized, integrated energy manager system on a newly designed mass transportation vehicle. It represents the first such use of EPDM.

EPDM is utilized for both the front bumper and fascia and for the rear bumper system. One of the three modules comprising the front bumper system has an as-molded weight in excess of 40 pounds, making it the largest bumper component produced to date. In all, 11 molded parts are supplied for this vehicle having a combined weight of 250 pounds of EPDM for each coach.

The efficiency of the concept to manage energy is demonstrated by the fact that this 24,000 pound vehicle is rated capable of sustaining repeated seven-mile-per-hour barrier impacts without damage. The as-tested performance levels of the front bumper system far exceed that of any other system used in mass transportation vehicles. The system is capable of withstanding impacts from passenger cars as well as barrier impacts.

The concept required a tough, resilient, abuse-resistant and durable material for the ten year service life anticipated. When the system is scaled down to passenger car proportions and requirements, the results are significant. In addition to bumper systems, the concept could be applied to other exterior parts such as fenders, hoods and deck lids.

Fabric/Rubber Concepts

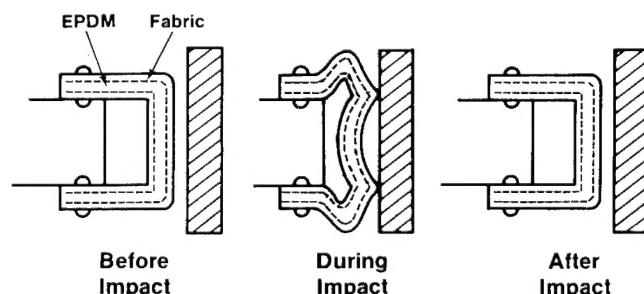


Figure 9 — Diagram shows principle of EPDM energy manager.



Figure 10 — GM RTS-2 coach uses EPDM energy manager and fascia.

CONSIDERATIONS IN FASCIA APPLICATIONS

As evident by these varied current applications, EPDM has come a long way from the stone deflector and small bumperette market it served in the past several years. Today, EPDM is on the threshold of the fascia market envisioned in its early development for exterior automotive uses. And, based on past experience, there are a number of factors that should be taken into account when considering EPDM for fascia applications.

Molding Machinery — The first of these is equipment for producing EPDM fascia. Today, most major injection molding machine manufacturers can provide, on essentially an off-the-shelf-basis, very large rubber molding machines at no significant cost premium over their thermoplastic press counterparts. Of additional significance is the fact that plastic machines can be converted to rubber processing with relative ease. The conversion can be done quickly, and at modest cost, by simply changing the screw and barrel and a few minor controls. The convertability of a plastic press to rubber processing or the reverse, is extremely desirable from a financial standpoint because it minimizes the risk involved when purchasing a new piece of equipment to process a specific material for fascia.

Tooling — A second factor, which was touched on previously, is production tooling. Because of the molding temperature of approximately 375°F. and the pressures involved, hardened steel chrome plated molds are recommended for injection molding EPDM. However, the cost per mold cavity is typical of what would be paid for a similar injection molding tool for thermoplastics. While steel molds may be somewhat more costly than other types such as nickel shell molds, they provide a very important advantage in design versatility.

The example of the inability of modifying the nickel shell tool to incorporate the outboard bumperettes for the Monza rear fascia was discussed previously. Another example of steel tool versatility might be where a released part proves inadequate in stiffness. This might be compensated for by adding a few stiffening ribs to the part. These ribs could easily be machined into a steel mold; however, such modification is not possible with a nickel shell mold. Instead, engineers would probably have to resort to stapling a reinforcing bar to the part.

Scrap Reduction — Considerable progress has been made in reducing scrap through improvements in mold design and processing techniques. EPDM is a thermosetting material and is not recyclable. Initially, when molding large parts of EPDM, concern was raised about quantity of waste or scrap associated with each part. Up to 25 percent of unusable scrap in the form of sprues, runners and gates could be expected. In addition, out-of-mold rejects often ran in the range of 5 to 10 percent. This is no longer the case today. Part scrap rates have been reduced to less than 10 percent and out-of-mold rejects are consistently less than 3 percent. A final point of consideration is that EPDM releases readily from the mold without the use of either an internal or external mold release. This permits the use of automatic ejection techniques which reduce cycle times and provide a safer operation for equipment operators.

Painting — Techniques and equipment for painting EPDM parts have been developed on a full commercial scale, have been widely publicized, and therefore need little comment. The overall process is simple and involves four basic steps: cleaning, pretreatment with a patented UV irradiation procedure which alters the surface to obtain adhesion of a flexible primer; priming; then topcoating, in that order. This fully automatic system has been in commercial use for four years and has proved to be extremely reliable, reproducible and relatively inexpensive. The weatherability of flexible top-coats has also been fully demonstrated on a commercial basis.

Finishing Operation

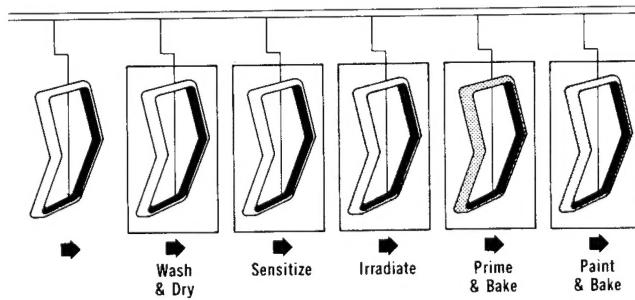


Figure 11 — Diagram shows painting steps used with EPDM.

Decorative Stripes — With further regard to finishing, studies are now underway to determine the feasibility of applying decorative tape striping to EPDM parts — a procedure not possible with certain RIM formulations because of out-gassing, a phenomenon which does not occur with EPDM.

Under study are adhesive backed, decorative tape stripes, either colored or in a bright metallic finish, applied directly over painted fascia. Hot melt adhesive systems are also being explored for adhering the stripe. And, on the basis of some preliminary work, there is evidence that decorative tape could be applied before paint and withstand the 250°F. paint oven. This suggests the possibility of tape stripe application at the fascia molder's plant prior to shipment to the assembly point.

FUTURE POSSIBILITIES

There are improvements in both EPDM compounds and processing techniques which the automotive industry can expect in the years ahead. Based on current research and development programs, EPDM's that are faster curing to provide shorter cycle times, and which possess even better low and high temperature properties, are distinct possibilities. Also, the family of EPDM compounds will be expanded to include much stiffer candidates which are both impact resistant and pseudo structural, for use in both low and high abuse applications. These will be based on the previously discussed rubber /fiber composites.

Thermoplastic EPDM — As mentioned earlier, EPDM is available in both thermoset and thermoplastic grades. However, to date, the use of the thermoplastic types has been confined primarily to sight shields and small exterior parts. Thermoplastic EPDM's do provide rubber-like properties and are recyclable and processable on standard plastics equipment. However, they do not have resilient properties to the degree characteristic of the thermosets. As a sight shield material, they provide equivalent stiffness at lower part thickness and offer advantages in cost and weight reduction.

In the future, thermoplastic EPDM's are expected to include types which are more impact resistant, will offer improved surface mar resistance, and will range in stiffness from soft to very hard. The rigid candidates will probably be fiber reinforced and are expected to find utility as low abuse, high appearance components.

Processing Equipment — Innovations in processing equipment are also anticipated, such as adaptively controlled single and dual injection presses capable of processing both thermoset and thermoplastic EPDM. Molds will be computer designed and will incorporate sprueless, runnerless systems to reduce scrap and permit greater design latitude. These same molds will incorporate automatic ejection to further improve cycle times.

Some of these innovations are at an advanced stage of development. Currently on stream is a 3,000 ton injection press which can, without conversion, process either thermoset or thermoplastic EPDM. EPDM fascia parts are currently

being produced using runnerless molds which greatly reduces scrap and part trimming. And, a rheological computer model has been used to both design molds and optimize cycle times on several 1977 parts now in production.

A promising lead for making prototype and low production molds by nickel deposition over a low cost substrate, such as concrete, is also being explored.

In addition, new type finishes that may ultimately permit on-line painting of fascia along with the sheet metal are in the early development stage. The resistance of EPDM to paint bake temperatures makes this development feasible.

With the increasing concern for cars that are lighter in weight, damage resistant and more efficient, use of resilient fascia coupled with an energy absorbing system provides an economical and efficient means of achieving these ends.

Recently, a leading automotive industry executive predicted that by 1980, some 40 percent of new car production would incorporate resilient fascia. The established performance of EPDM, combined with its ability to meet a broad spectrum of desirable properties, make it a viable candidate for the variety of exterior resilient parts that will be required in future automobile assemblies.

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